Alberta ENERGY
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Performance Characteristics of Energy-Efficient Residential Furnaces

Projects supported in part
by the Alberta/Canada
Energy Resources
Research Fund

Cover Photo: A gas-fired, power-vented unit heater was one of several furnace products developed by Climate Master Inc. of Edmonton specifically for Alberta's climatic conditions. The project received financial assistance from the Alberta/Canada Energy Resources Research Fund.

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Foreword

Since 1976, numerous projects have been initiated in Alberta by industry and by academic research institutions which are aimed at better utilization of Alberta's energy resources.

These research, development and demonstration efforts were funded by the Alberta/Canada Energy Resources Research Fund (A/CERRF), which was established as a result of the 1974 agreement on oil prices between the federal government and the producing provinces.

Responsibility for applying and administering the fund rests with the A/CERRF Committee, made up of senior Alberta and federal government officials.

A/CERRF program priorities have focused on coal, energy conservation and renewable energy and conventional energy resources. Administration for the program is provided by staff within the Scientific and Engineering Services and Research Division of Alberta Energy.

In order to make research results available to industry and others who can use the information, highlights of studies are reported in a series of technology transfer booklets. For more information about other publications in the series, please refer to page nine.

Performance Characteristics of Energy-Efficient Residential Furnaces

Approximately 16 per cent of all the energy consumed in Canada is used to heat residential buildings. In Alberta, homes are usually heated by gas-fired furnaces having seasonal fuel efficiencies ranging from 55 to 60 per cent. This means for every 100 units of natural gas that are burned, 55 or 60 units heat the home while the energy contained in 40 or 45 units is lost up the chimney.

To reduce these heat losses, furnace manufacturers have introduced improved models that are more energy efficient, but they are also substantially more expensive than conventional furnaces.

To determine whether these newer models are as energy efficient as claimed by manufacturers, and to ascertain whether payback periods are reasonable on the basis of fuel cost savings, a fundamental study of furnace efficiency was undertaken, and partially funded by A/CERRF. It was complemented by other investigations which identified aspects of furnace design which could be further refined.

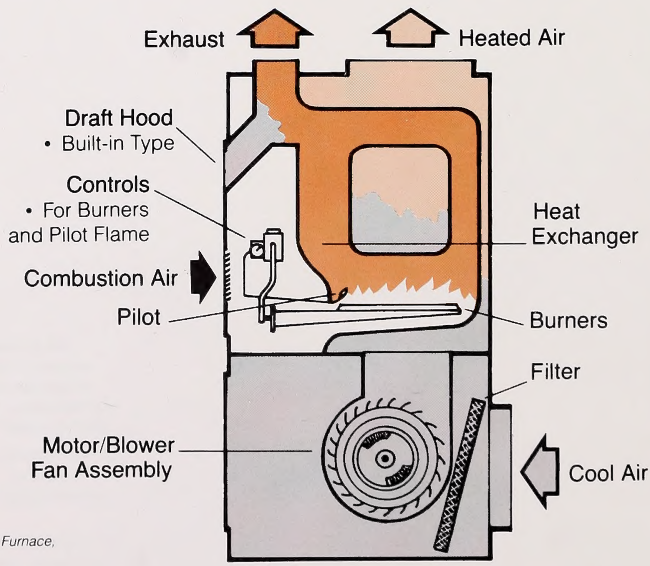
A Study of Furnace Performance

Six gas-fired furnaces, typical of designs marketed in Alberta since 1980, were tested to determine their fuel efficiency and cost effectiveness. In this University of Alberta study, a conventional forced air furnace was used as reference for five medium- or higher-efficiency models.

Sources of Heat Loss

In conventional furnaces, heat losses occur for several reasons. Principal among them is the limited size of the heat exchanger, which does not allow all of the combustion heat to be transferred to the air that is circulated throughout the house. Consequently, combustion gases often leave the heat exchanger and enter the flue while still quite hot, carrying with them a significant portion of available fuel energy. This is called sensible heat loss. It can account for 15 to 20 per cent of total heat losses.

Cross-sectional Views of Conventional and High-Efficiency Furnaces



Conventional

(Illustrations adapted from: *Selecting A New Furnace*, Alberta Energy, Pub. No. I/17-#6)

Other losses include latent heat (up to 10 per cent) present in uncondensed water vapor, a major component of flue gases; heated room air (eight to 15 per cent) lost up the stack during furnace operation and particularly during shutdown; heat lost by continuously operating the pilot burner (five to seven per cent) and oversizing (up to three per cent), which is needed only during especially cold weather.

Heat Loss Reduction

In newer furnaces, these losses have been reduced, either by making changes to conventional designs or by introducing different design concepts. For example, one furnace tested during this study, the ICG Conserver, employs a motorized stack damper to prevent warm room air from escaping up the stack. Because this prevents removal of combustion gases from the pilot burner, an electronic spark ignitor is used instead, thus eliminating energy losses caused by a continuously operating pilot.

Another furnace, the mid-efficiency AIRCO Turbo, employs electronic ignition and an induced-draft fan to control the intake of combustion air, thereby achieving more efficient combustion with relatively less excess air. Also, its improved heat exchanger is designed to reduce losses of sensible heat.

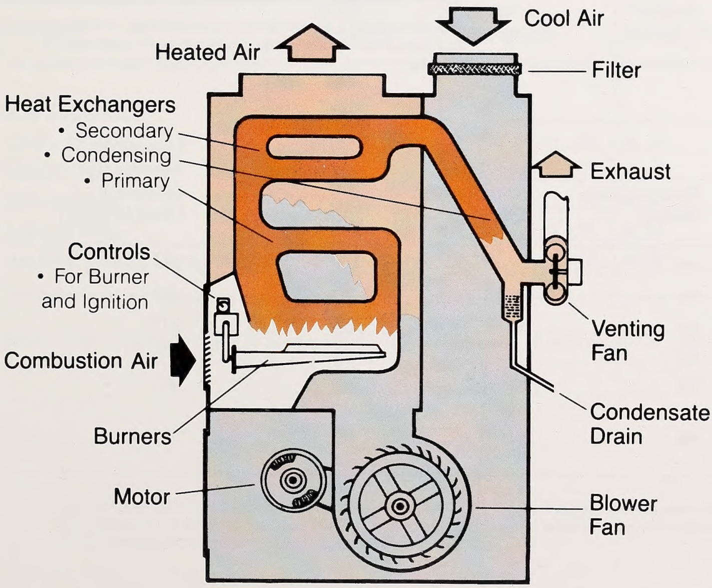
Three high-efficiency furnaces were tested. These designs use several heat exchangers, instead of one, and in the last exchanger flue gases are condensed to recover latent heat. This allows replacement of the exhaust stack, common to conventional furnaces, with a small vent, which pipes exhaust gases to the outside of the house, and piping, which transfers liquid condensate to a floor drain.

One of the high-efficiency units, the ICG Ultimate, was regarded as revolutionary when it was introduced but it is no longer produced because it has been surpassed by newer technology. It uses an induced-draft blower and electronic spark ignitor.

In the AMANA Energy Command Furnace, which is another high-efficiency, condensing design, combustion heat is transferred to the room air by a mixture of water and glycol, which is circulated through the heat exchanger.

A different design concept is employed in the Lennox Pulse furnace. Instead of a conventional burner assembly, a small, finned chamber is used to generate pulsed explosions of fuel which draw in combustion air and expel exhaust products.

A conventional furnace, the ICG Standard, was tested for reference purposes.



High-Efficiency

Furnace Performance

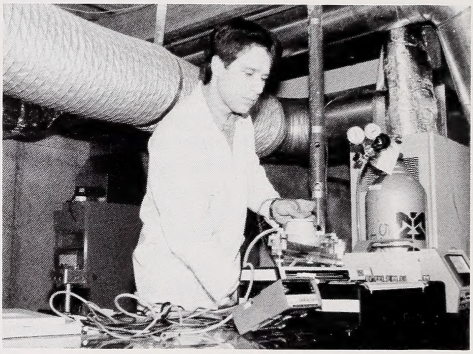
Furnace performance was measured in the laboratory and by installing each unit in a housing module at the Alberta Home Heating Research Facility, where the energy characteristics of test homes have been monitored for several years using electric heating.

In the laboratory, steady state fuel efficiency was measured according to standard procedures used by furnace manufacturers. In this test, each furnace was operated continuously, which allows measurement of maximum efficiency. However, this mode of operation is regarded as an inaccurate representation of actual operation in a residence, where furnaces cycle on and off throughout the heating season and seldom turn on for several months. Consequently, the study also included measurements of seasonal fuel efficiency using a procedure proposed by the Canadian Gas Association to more accurately determine heat losses caused, for example, by operating a pilot burner year-round.

In both these tests, measurements were made of flue gas temperatures during warm up and cool down, as well as flue gas carbon dioxide levels. For condensing models, the rate of condensate formation was also measured.

When operated in the test home over three- or four-month intervals, fuel efficiency was determined by measuring the amount of energy required to maintain room temperature at a particular level. This involved consideration of the thermal characteristics of the building envelope, the severity of the climate, air infiltration, solar radiation, heat conduction and the amount of purchased energy required to offset heat losses.

Measured fuel efficiency values showed good agreement with rated values; however, the measured seasonal efficiency of the conventional furnace (67 to 72 per cent) was higher than the expected range of 55 to 60 per cent, thus diminishing the difference between conventional and higher-efficiency furnaces and lowering the economic advantages of the most efficient units.



The fuel efficiency performance of conventional, mid-efficiency and high-efficiency furnaces was tested at the University of Alberta.

Fuel Efficiency (%)

Furnace	Steady State Rating	Measured Steady State Efficiency	Measured Seasonal Efficiency (Laboratory)	Measured Seasonal Efficiency (Test Module)
ICG Standard	77	72	67	71[a]
ICG Conserver	77	69	76	80[a]
AIRCO Turbo	84	81	83	91[b]
ICG Ultimate	92	92	92	92
Lennox Pulse	96	97	96	98
AMANA Energy Command	96	96	95	92

[a] includes energy recovery of about three per cent obtained from the exposed flue pipe that extends from the furnace to the class B vent (chimney)

[b] moisture condensation occurred in the furnace flue pipe, resulting in an eight per cent increase in efficiency. For long-term occupant safety, this mode of operation is not recommended.

(Source: *A Study of the Performance of Six Residential Natural Gas Furnaces*, Kasha, J.F. and J.D. Dale, May 1986)

Economic Considerations

One way of expressing the economics of furnace ownership is to calculate the payback period, which is the time required to recoup incremental capital costs in excess of conventional furnace costs by means of lower fuel bills. Another way to express cost effectiveness is to calculate internal rates of return on the capital investment. These calculations include cost savings that are possible beyond the payback period. To be meaningful, a rate of return should exceed the rate of interest that homeowners would be expected to pay for money borrowed to purchase a furnace.

To demonstrate the sensitivity of payback and rates of return to differences in energy cost and the severity of climate, the investigators calculated results for furnace operation in both Edmonton and Toronto. While higher fuel costs in Toronto made it possible to justify the added expense of more efficient furnaces, in Edmonton it would be more economical to purchase an upgraded conventional furnace or a mid-efficiency model rather than a high-efficiency unit. However, in poorly insulated homes there is greater incentive to choose a high-efficiency model.

Selection of Warm Air Furnaces for Residential Housing

The amount of heat that a furnace must supply to energy-efficient homes is substantially less than to older, poorly insulated dwellings. Depending on the level of insulation and airtightness of the home, some newer designs need as little as 26 per cent of the heat required by houses that were built in the 1950s and '60s.

This reduction in energy consumption is due to better insulation, fewer air leaks and effective vapor barriers which are used in energy-efficient dwellings.

Despite this dramatic decline in home heating requirements, some furnace manufacturers are still designing their products as though the only homes in which they will be used consume as much energy as 30-year-old dwellngs. Although newer furnaces are available which are more energy efficient (and more expensive) than conventional designs, it is questionable whether the size of the heating elements and the air distribution mechanisms used in these furnaces is matched as well as it could to the heating requirements of newer homes.

Economic Results

■ **Edmonton** □ Toronto

Furnace	Initial Costs ($)	Annual Savings ($)		Payback Period (Years)		Internal Rate of Return (%)	
ICG Standard	1 000	–	–	–	–	–	–
ICG Conserver	1 200	■ **40**	□ 53	■ **5**	□ 4	■ **20**	□ 27
AIRCO Turbo	1 500	■ **78**	□ 101	■ **6**	□ 5	■ **15**	□ 20
ICG Ultimate	1 650	■ **83**	□ 111	■ **8**	□ 6	■ **12**	□ 17
Lennox Pulse	2 450	■ **108**	□ 142	■ **13**	□ 10	■ **6**	□ 8
AMANA Energy Command	3 150	■ **107**	□ 139	■ **20**	□ 15	■ **1**	□ 3

(Source: *A Study of the Performance of Six Residential Natural Gas Furnaces*, Kasha, J.F. and J.D. Dale, May 1986)

In a study by J.E. Sworder Engineering Ltd., furnace heat exchanger sizes and air circulation rates were calculated for a single family, three bedroom bungalow exposed to Alberta's winter conditions. By calculating the required heating loads for three outdoor air temperatures (0°, -18° and -33°C) and for three levels of insulation, theoretical furnace air circulation rates were determined for three temperature rise conditions across the furnace heat exchanger.

Whereas conventional furnace heat exchangers are designed to raise the temperature of air passing over them by 50°C, this investigation showed that a temperature rise of only 25°C is needed in energy-efficient homes, and a temperature rise of 15°C is adequate in super energy-efficient dwellings. However, lower heating loads within homes and smaller temperature differentials inside furnaces do not imply that lower air circulation rates can be used. The Sworder study showed that the volume of air that is circulated by a furnace fan cannot be reduced to any degree for the range of conditions covered in this study.

Because of the wide differences in energy-efficient designs found in the housing market today, it was recommended that furnaces should be designed in such a manner that prospective buyers could select from a range of units having heat exchangers that better approximate the heating loads of specific dwellings.

Development of Higher-Efficiency Gas-Fired Heating Appliances

Because most furnace manufacturers are located in eastern Canada and the U.S., their products are not necessarily designed to operate at peak efficiency in Alberta's cold, dry winter conditions or at Alberta's relatively higher elevation.

For this reason, one Alberta manufacturer, Climate Master Inc., received A/CERRF funding to develop three types of energy-efficient, natural gas furnaces designed for Alberta conditions.

Standard Furnaces Equipped with Electronic Vent Dampers

Standard gas-fired furnaces normally achieve an annual fuel utilization efficiency of only 55 to 65 per cent, partially because substantial amounts of heat escape up the chimney when the burner is off. By installing an electronic vent damper in the furnace flue, which restricts the air passage when the burner is off but automatically opens when the burner fires, Climate Master was able to raise fuel efficiency to 70 per cent. Furnaces modified in this manner received certification from the Canadian Gas Association and subsequently were released to the marketplace.

High-Efficiency, Non-Condensing Residential Furnaces

A line of high-efficiency, non-condensing (HENC) residential furnaces was developed and certified. The design uses fans to control the combustion process by mixing the proper amounts of combustion air and fuel, whereas in standard atmospheric furnaces the mixing process relies on convection and gravity. While avoiding flue gas temperatures below 350°F, which could result in condensation of the gas mixture and subsequent corrosion of some furnace components, a non-condensing furnace design was achieved by adding internal baffles to the heat exchanger, increasing the burner angle and using a draft inducer fan. This resulted in a furnace having an annual fuel utilization efficiency of 80.5 per cent at high altitudes or 82 per cent at sea level.

Light Commercial Unit Heaters

HENC technology was used to produce two types of induced-draft unit heaters designed for use in light commercial applications. One type, called a power-vented unit heater, was designed for indoor environments that experience changes in atmospheric pressure. The second type, a sealed combustion unit heater, is meant to be used where changes in air pressure are accompanied by the presence of corrosive or dangerous chemicals in the air. Units ranging in size from 70 000 to 260 000 BTUs per hour were developed, certified and made available for general sale.

Because these appliances are made in Alberta, they are readily available in the province and are less expensive than products made elsewhere. It is anticipated these two advantages will encourage more Albertans to purchase energy-efficient furnaces and heaters.

At Climate Master Inc. in Edmonton, two types of residential, gas-fired furnaces were designed and developed. Here, one is undergoing tests at the factory.

Survey of Medium- and High-Efficiency Gas Furnaces

Since the introduction of medium- and high-efficiency furnace models by several manufacturers, some homeowners have been reporting problems relating to corrosion, high maintenance costs and high indoor moisture levels.

To better define problems arising in Alberta, and to propose some solutions, a survey was made of Alberta furnace distributors, homeowners, heating contractors, regulatory agencies and utilities, as well as Canadian and U.S. researchers involved in furnace development.

Those furnaces included in the survey were: AIRCO Turbo; AIRCO Turbo Plus; AMANA HTM Plus, and Energy Command; Carrier Super Saver, and Weathermaker; Clare Command Air, and Megasave; Coleman DES, and THE; Duomatic Olsen Challenger, and Ultramax; Flamemaster Energy Conserver; ICG Ultimate I, II and III; Keeprite 80, and 96; Lennox Conservator III, and Pulse.

The survey covered nearly 600 incidents involving higher-efficiency furnaces in Alberta. Of the total, 58 per cent were related to furnace shutdown caused by failure of components such as temperature and pressure switches and induced-draft fan motors.

Sixteen per cent of the reported problems were associated with improper installation by heating contractors who did not follow manufacturers' instructions. Other aspects of concern were noise (seven per cent); servicing and maintenance (six per cent); condensation, whether it was inside homes (three per cent), inside the furnace flue (three per cent) or in the heat exchanger (one per cent); icing at the flue terminal and on the side of the house (three per cent); homeowner discomfort (two per cent) and corrosion (two per cent).

While furnace manufacturers are being urged to correct certain design features to minimize concerns about some problems, the furnace manufacturing industry as a whole believes homeowners and installers must accept the fact that higher-efficiency furnaces are mechanically more complex than conventional furnaces. This means heating contractors should become better trained in their installation techniques and maintenance, and homeowners should avoid tinkering with these types of furnaces.

Contacts

Further information about "A Study of the Performance of Six Residential Natural Gas Furnaces" is available from:

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